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Research, part of a Special Feature on Long-term Vulnerability and Transformation

Resisting Diversity: a Long-Term Archaeological Study

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ABSTRACT. The value of "diversity" in social and ecological systems is frequently asserted in academic and policy literature. Diversity is thought to enhance the resilience of social-ecological systems to varied and potentially uncertain future conditions. Yet there are trade-offs; diversity in ecological and social domains has costs as well as benefits. In this paper, we examine social diversity, specifically its costs and benefits in terms of decision making in middle range or tribal societies, using archaeological evidence spanning seven centuries from four regions of the U.S. Southwest. In these nonstate societies, social diversity may detract from the capacity for collective action. We ask whether as population density increases, making collective action increasingly difficult, social diversity declines. Further, we trace the cases of low diversity and high population density across our long-temporal sequences to see how they associate with the most dramatic transformations. This latter analysis is inspired by the claim in resilience literature that reduction of diversity may contribute to reduction in resilience to varied conditions. Using archaeological data, we examine social diversity and conformity through the material culture (pottery styles) of past societies. Our research contributes to an enhanced understanding of how population density may limit social diversity and suggests the role that this association may play in some contexts of dramatic social transformation.

Key Words: *archaeology; long-term; resilience; social diversity; vulnerability*

INTRODUCTION

Calls for enhancing and preserving social and biological diversity are in the news almost daily; both are foci of study and of action by ecologists, conservationists, and land managers, as well as the explicit goals of some social movements and government policies in various nations (see for example Folke et al. 2002). A growing literature on social-ecological systems, drawing from ecology, argues for the value of diversity in building resilience to a variety of perturbations (Chapin et al 1997, Walker et al. 1999, 2006, Elmqvist et al. 2003, Low et al. 2003, Ostrom 2005, Folke 2006, Ives and Carpenter 2007). For example, Folke has stated that "biological diversity is essential in the self-organizing ability of complex adaptive systems [Levin 1999] both in terms of absorbing disturbance and in regenerating and re-organizing the system following disturbance" (Folke 2006:257-258). However, there are trade-offs, as Anderies, Janssen, and others have argued (Anderies 2006, Anderies et al. 2006, 2007, Janssen and Anderies 2007, Janssen et al. 2007, Scheffer et al. 2001); diversity has costs, as well as benefits, in both ecological and social contexts. Social diversity can be expensive and may detract from the capacity for collective action. Biological diversity may, under some circumstances, slow the responses of ecosystems, thus lessening their capacity to continue functioning after disturbance (Kinzig and Pacala 2002). However, while economists and ecologists have begun to examine these trade-offs in contemporary contexts, we have no long-term studies of the advantages and costs of social diversity. The study presented here provides such a long-term perspective, drawing on the time depth available in the archaeological record, as well as exploring contexts that contribute to trade-offs in the value of diversity.

In this study, we assess the changing relationships among population density, social diversity, and transformation. Our study examines these relationships over several centuries, from 1000 CE to 1600 CE, across the broad landscape of the U.S.

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Southwest (Fig. 1) using archaeological data on prehistoric and early historic settlements and the distribution of pottery of different styles. The societies we study either lack or have minimally developed institutionalized hierarchies; these are what archaeologists call “middle range” or “tribal” societies, because they are more complex than those of foragers and less complex than states. Our interests are twofold. First, to understand factors that might contribute to changes in diversity, we evaluate the hypothesis that, in middle range societies, social conformity becomes increasingly important as population density increases. We find support for this hypothesis in a strong association between low levels of material culture diversity and high levels of population density. Second, we investigate the effects of these changes in diversity, following from resilience literature that postulates the importance of diversity for maintaining resilience in social-ecological systems. We explore whether the low diversity that we observed in the context of high population density had the effect of lowering resilience by assessing whether these low diversity contexts subsequently experienced the most severe transformations. In this exploration, we do not suggest there was a unilinear causal relationship between low diversity and transformation; rather, we consider the overall pattern of association to establish the potential for using the archaeological record to examine the long-term effects of different levels of diversity.

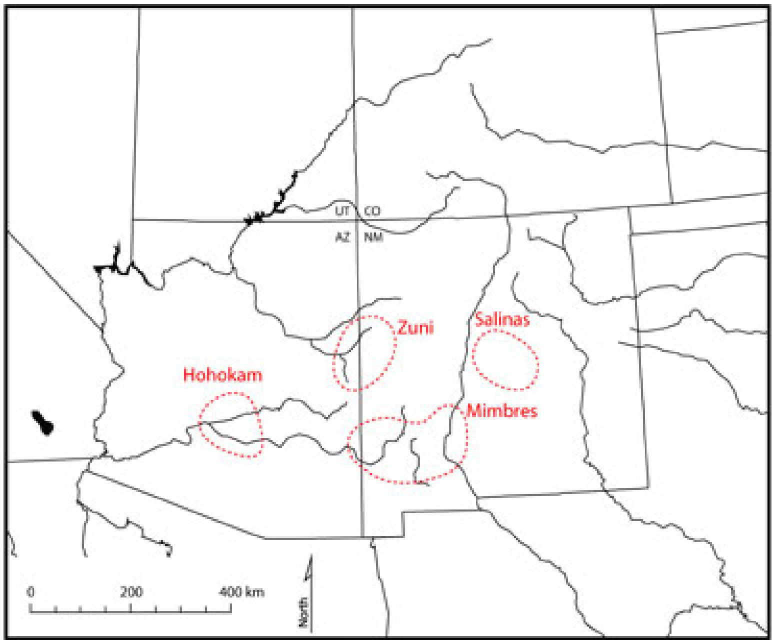
DEFINING THE RESEARCH PROBLEM IN THE MIMBRES CASE

The Mimbres archaeological region in southwest New Mexico, as well as the Hohokam region in central and southern Arizona (Fig. 1), have become cornerstones of the growing linkages between archaeology and the resilience perspective (e.g., Redman and Kinzig 2003, Anderies 2006, Nelson et al. 2006, 2010, Hegmon et al. 2008, Redman et al. 2009). A brief review of changes in diversity through the Mimbres sequence sets the stage for the research we pursue here.

The Mimbres region, settled by small-scale farmers, experienced fairly steady population growth beginning around 550 CE (Fig. 2). This culminated in a period of intensification during what is known as the Mimbres Classic period (1000-1130 CE), characterized by consolidation and settlement in fairly large villages, supported in part by small-scale irrigation systems. At the end of the Classic period, during a time of climatic downturn, both the cultural tradition and the settlement organization changed; many people left their villages and left the region altogether, while others shifted from villages to small dispersed hamlets and remained in the region. We have previously characterized this sequence as a period of growth and accumulation (in resilience terms this is an r-to-K-phase), followed by a release and reorganization (Nelson et al. 2006).

Various kinds and levels of diversity have been documented throughout this sequence. Here we focus on painted pottery, including both the painted designs and the kinds of painted pottery present. Painted designs can convey aspects of social identity, thus a low diversity of painted designs is indicative of some degree of shared identity, a component of conformity. Various kinds of pottery are made in different regions and thus the diversity of types is indicative of the diversity of inter-regional interactions. Mimbres pottery is renowned for its spectacular black-on-white geometric and representational designs (Fig. 3), and there is good evidence that early Mimbres designs (ca. 750 CE) combined local styles with some derived or copied from the Hohokam tradition, made approximately 400 km to the west (Brody 2004; Fig. 4). The growth of Mimbres was paralleled by even larger scale growth in what is known as the Hohokam regional system (Abbott et al. 2007), a vast network of material and information exchange that expanded nearly into the Mimbres region by the 11th century. However, by the early 11th century, people in the Mimbres region turned away from their immediate neighbors in the Hohokam region; they dropped Hohokam designs from their repertoire (Hegmon and Nelson 2007) and shifted to a design scheme characterized by a high degree of homogeneity. Although people painted many different design motifs, e.g., jack rabbits, birds, deer, etc., the structure of the designs, the way they are laid out and framed, is highly redundant (Hegmon and Kulow 2005; Fig. 5). In addition, painted types other than this Mimbres tradition are extremely rare. This homogeneity, in both the painting tradition and the types of painted pottery, characterizes the Mimbres Classic period, the time of highest population density and most extensive farming. This period of low diversity and high population density ended with a substantial depopulation and dramatic institutional change in the region. A strikingly different pattern is seen in the subsequent period of

Fig. 1. US Southwest showing the regions of the four cases.

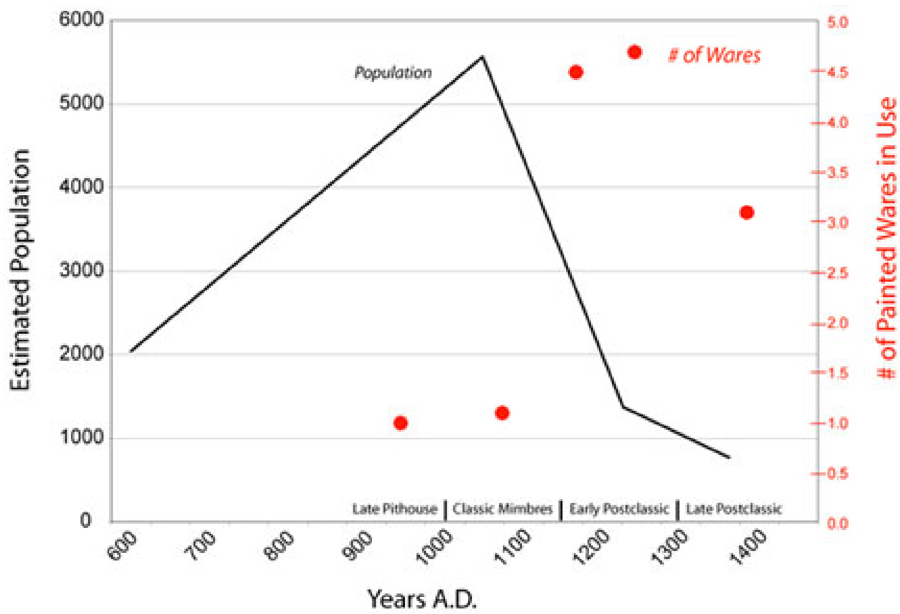


reduced population and dispersed settlement, aptly known as the Mimbres Reorganization phase (ca. 1150-early 1200s CE). The diversity of material culture is much greater; people made and imported many kinds of pottery indicative of ties to various surrounding regions.

We have previously argued that these changes in observable levels of diversity in pottery, and in other forms of material culture not discussed here, are components of the changing social processes involved in consolidation and reorganization (Hegmon et al. 1998). That is, the Mimbres Classic period homogeneity was a result of an internally directed "Mimbres focus," including an emphasis on conformity that served as a means of maintaining social control in the large, densely packed villages that were increasingly isolated from other centers of population in the U.S. Southwest. The Reorganization phase diversity represented both a relaxation of this conformism and the establishment of an extensive network of ties that possibly replaced the more intensive networks of contacts people would have had in large villages of the preceding period.

The empirical details and theoretical justification of this scenario and interpretation have been explored in other publications (Hegmon et al. 1998, Nelson 1999, Nelson et al. 2006, Hegmon and Nelson 2007). Our purpose here is to assess whether the specific patterns we see in the Mimbres case are representative of the Southwest as a whole. Specifically, is there a relationship between increases in population density and social conformity, indicated by low levels of material culture diversity? If yes, does this contribute to a loss of resilience, increasing the likelihood of subsequent transformation? In the analyses that follow, we expand the spatial and temporal scale of our work considerably, moving from this single prehistoric case to examine pan-Southwestern trends across an area of over 200,000 km² and through a period from the 11th to the 17th centuries AD. This perspective puts the Mimbres case in a much larger context and, perhaps most importantly, relates the archaeological cases to broader issues regarding the relative costs and benefits of diversity for society more generally.

Fig. 2. Population change and associated changes in painted ceramic diversity in the Mimbres region.



SOCIAL DIVERSITY

There are, of course, many different kinds of diversities, and many ways archaeologists can measure diversity and trace changes over time (e.g., Leonard and Jones 1989, Hegmon 1995). Discussions about diversity in the resilience literature rely heavily on an ecological understanding of diversity, which we replace with an anthropological perspective in this study. Ecologists distinguish between functional and response diversity in ecosystems, with functional diversity being the number of functions within an ecosystem, e.g., nitrogen fixing, respiration, decomposition; the functions depend on the kind of ecosystem under consideration, and response diversity depends on the array of responses to disturbances within members of a functional group, e.g., among the nitrogen fixers. Both are thought to enhance resilience in ecosystems, within limits, and both have costs (Chapin et al. 1997, Walker et al. 1999, 2006, Elmqvist et al. 2003). Thus, the relationship between diversity and resilience even in the ecological realm is complex and requires attention (Ives and Carpenter 2007).

Diversity in social and cultural contexts is especially complex and cannot borrow directly from the ecological concepts of functional and response diversity. Thus, in this section we address social diversity as understood from social theory in anthropology. Because individuals or social groups can take on various roles, they may contribute variously to social diversity. Furthermore, there are many kinds of diversities in the social realm, e.g., of styles, tastes, social classes, etc., and these have costs and benefits, as do aspects of ecological diversity. We cannot encompass all aspects of a social system within a single study; we focus here on style diversity as an indicator of one aspect of social diversity. Building from the Mimbres case described above, we focus on diversity in the style of material culture, specifically painted pottery, which may have communicated information about identity in social ties or interaction. Also building from the Mimbres case described above, we recognize that diversity or homogeneity in one realm, in this case pottery style, does not imply uniform diversity or homogeneity across all dimensions of society. Our paper treats one aspect of social diversity as a starting point for a more nuanced treatment of the social realm in discussions

Fig. 3. Classic Mimbres black-on-white bowl dating to the end of that period (ca. 1130 CE).

of the role of diversity in resilience of social-ecological systems. In this section, we discuss relationships between material culture and social identity and interaction, focusing on how homogeneity of material style can serve as evidence of social conformity in the archaeological record.

Material style and social conformity

Archaeologists have developed an enormous literature regarding style in material culture (summaries and synthetic treatments can be found in Plog 1983, Conkey and Hastorf 1990, Hegmon 1992, Carr and Neitzel 1995). Although many aspects of style, e.g., the color and design painted on pottery, do not affect the technological function of the artifact, material style can be seen as having "function" in social relationships. Style can serve to communicate all sorts of information, ranging from "this kind of black pot is particularly well made" (Longacre et al. 2000) to "we believe the universe to be organized according to these principles" (David et al. 1988) to "I am a such-and-such person and thus part of this social network" (Wiessner 1983, 1984). The last is of particular relevance to the argument we develop here about levels of diversity, population, and transformation.

Material culture style is a particularly important component of social relationships in subsistence-based, agricultural economies around the world, most of which can be characterized as middle range societies. Nearly all social formations in the prehistoric U.S. Southwest after 500 CE fit this general classification, although there is some evidence for a degree of hierarchy in some times and places (see overview in Hegmon 2005). In such societies, material culture similarity, as well as other activities such as participation in ritual (Rappaport 1971), can serve to establish and maintain social relationships, solidarity, and the capacity for collective action. The causes of such stylistic similarity are various. Stylistic homogeneity has been interpreted as indicative of regional integration and the evolution of tribal social networks, in the Southwest and elsewhere (Braun and Plog 1982). Homogeneity may be the outcome of what is known as biased conformist transmission, which refers to the tendency of people to copy or imitate ideas or behaviors of the majority of the group, in part because "individuals use the frequency of a trait as

Fig. 4. Hohokam (left) and early Mimbres (right) bowls with horned toad designs. Similarities include diamond-shaped heads and bodies, positions of limbs and digits, and triangular framing. Hohokam toad is from the Arizona State Museum and the Mimbres toad from the Amerind Foundation.

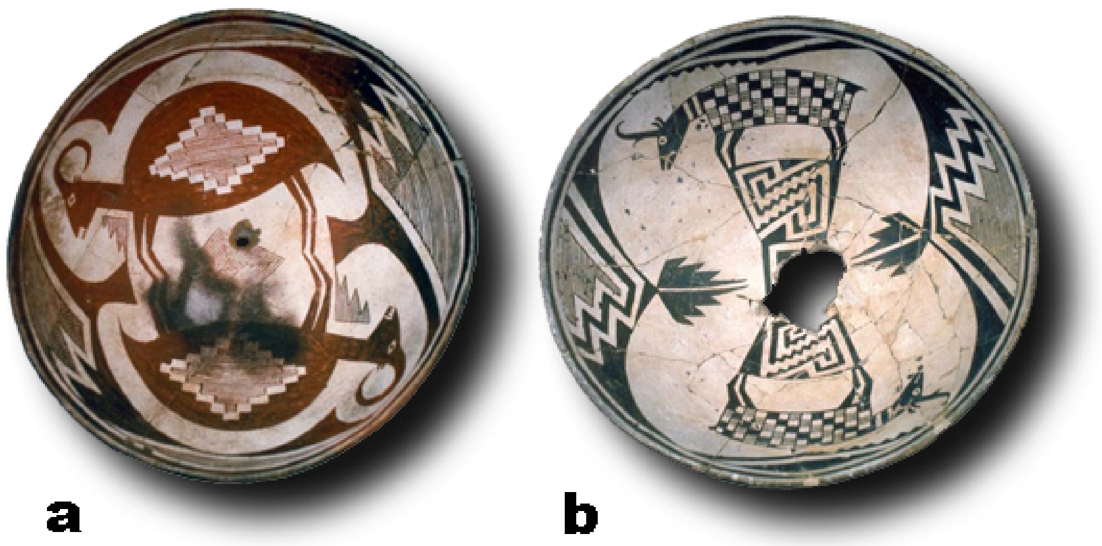
an indirect indicator of its worth" (Henrich 2001:1003; see also Boyd and Richerson 1985, Kohler et al. 2004). Homogeneity may also be a product of an unquestioned tradition, what Sackett (1982) calls isochrestic variation, or people may consciously adopt a particular style to signal their linkages with a particular group. In yet other cases, stylistic homogeneity may result from a social emphasis on conformity, pressure to fit in with the group, which may involve relationships of power and authority. However, very often in middle range societies, such conformity is imposed not by elites but from within, through gossip about and nonacceptance of those who do not conform. Sociologist Pierre Bourdieu describes this well:

> *Doing one's duty as a man means conforming to the social order, and this is fundamentally a question of respecting rhythms, keeping pace, not falling out of line. 'Don't we all eat the same wheatcake (or the same barley)?' 'Don't we all get up at the same time?' These various ways of reasserting solidarity contain an implicit definition of the fundamental virtue of conformity, the opposite of which is the desire to stand apart from others.* (Bourdieu 1977:161)

The importance of conformity in social relations in Southwestern cases is well established with both archaeological and ethnographic examples. Among the Navajo, Shepardson and Hammond (1970) reported that people who conformed socially were well regarded and were offered help when in need. Similar reports for the importance of social conformity come from the Hopi (Aberle 1951, Titiev 1971, Wyckhoff 1986), and Kohler et al. (2004) found evidence of conformist transmission, seen in pottery style, in a period of population coalescence in the prehistoric northern New Mexico.

A large body of literature, ranging from archaeology to organizational theory, has postulated that such conformity is often associated with increases in

Fig. 5. Similarly structured Mimbres black-on-white bowls featuring representations of a) bighorn sheep, and b) pronghorn antelope. Images courtesy of the Peabody Museum of Archaeology and Ethnology, Harvard University.



group size, density, or scale (e.g., Johnson 1982, Kohler et al. 2004), and we have observed such in our own research in the Mimbres and other cases (Hegmon et al. 2008). These are some of the processes Braun and Plog (1982) view as being part of the evolution of tribal social networks. Kohler and others (2004), for example, have documented lower than expected diversity in pottery design style as people aggregated into villages for the first time in prehistoric northern New Mexico. They associate this limited diversity with conformist behavior that facilitates cooperation. Conformity can serve to reduce scalar stress in consensual decision making (Johnson 1982) in that it establishes a degree of sameness and a basis of communication, or to promote group cohesion in times of economic stress and competition (Hodder 1979). In other terms, conformity is a form of institutional structure that reduces transaction costs (North 1990). For example, conformity in contemporary contractual process such as banking or driving cars can reduce the amount of individual negotiation or outcome uncertainty. Conformity can result from sets of rules and norms, i.e., institutions, that govern how to be and how to act, whether or not these rules are codified. And although the conformity we are discussing is primarily evident in the symbolic realm, i.e., designs on painted ceramic vessels, it likely had repercussions in other behavioral realms.

Exploring social diversity and its relevance to resilience thinking

This literature on material style and social conformity suggests trade-offs that we consider in this paper. The expression and perhaps imposition of conformity may contribute to cooperation or consensual decision making and thus may be beneficial in some contexts, including times of increasing population density. However, the conformity simultaneously constitutes a reduction in diversity that may, in turn, contribute to a loss of resilience by lessening the capacity of the system to respond in varied ways. In essence, the reduction in diversity may increase short-term robustness at the expense of long-term vulnerability. This trade-off was apparent in the Mimbres case. The conformist Mimbres-focus, including the stylistic homogeneity and breaking off of extensive ties to other regions, may have been an intentional strategy, by the people of the Mimbres, to maintain a degree of social solidarity in times of increasing population and potential social and subsistence stress (see Henrich 2001 for an alternative to this perspective that emphasizes biased transmission). However, this conformity limited their responses to changing conditions and thus may have reduced the resilience of the system and contributed to the transformation and reorganization at the end of the Mimbres Classic period.

In this study, we use this interpretation of developments in the Mimbres case, along with the theoretical and empirical studies of diversity and conformity, as a basis for a two-part investigation in a larger, pan-Southwest context. First, we evaluate the hypothesis that social conformity in middle range societies is influenced by population density. Material culture homogeneity is used as an indicator of social conformity, and we find support for this hypothesis in a strong association between low levels of material culture diversity and high degrees of population density (see Kohler et al. 2004 for a similar outcome at a smaller scale). Obviously many factors, not just changes in social conformity, could contribute to changes in material culture diversity (Braun and Plog 1982). However, if diversity, and its converse, homogeneity, had no social meaning, we would expect that with greater numbers of people, diversity would increase (see Neiman 1995). Thus, if we find an association between increased population and decreased diversity, we can interpret the decrease in diversity as a result, at least in part, of conformist behavior in the material realm on which we focus.

Second, we explore those periods characterized by high population density and low material culture diversity with respect to major social transformations, because resilience thinking suggests that low diversity can contribute to reductions in resilience. That is, conformity may have contributed to resolving problems associated with immediate disturbances, while increasing vulnerability to other, large, infrequent disturbances that led to transformations. To pursue this line of thinking, we look at whether the major transformations in our centuries-long regional sequences are preceded by periods in which diversity was relatively low and population was relatively large and dense.

EVALUATING THE ASSOCIATION BETWEEN POPULATION DENSITY AND SOCIAL CONFORMITY

We begin by evaluating our hypothesis that social conformity becomes increasingly important as population density increases. This hypothesis would be supported if we find an association between low levels of material culture diversity, indicative of social conformity, and high degrees of population density. We conduct two levels of analysis to evaluate this hypothesis. The first is at a broad, pan-regional scale; the second considers data from well studied prehistoric to early historic archaeological sequences in four regions.

Operationalizing concepts using archaeological data

We assess population by estimating or using published figures for the populations of prehistoric and early historic settlements. These are archaeological sites that have been recorded and mapped, such that dwelling areas are indicated. Working at the broad, pan-regional scale, we simply look through time to see if the largest settlement concentrations in the U.S. Southwest correspond to the areas with the least ceramic diversity. Our second, more fine-grained examination of the hypothesis uses detailed archaeological settlement data compiled from four regions of the U.S. Southwest and associated pottery data from those regions for the period 1000-1680 CE. Each region has subregions, the occupations of which can be divided into temporal blocks representing different periods of occupation. For this study, the units of analysis are the temporal blocks of occupation in subregions; there are a total of 35 such time-space units for which both ceramic and population data are available. A list of the periods and subregions by case is provided in Table 1; subregions are shown in Figure 6. We calculate population densities for each period of occupation within each subregion. These population density values are also used in the interpretations that follow.

We assess material culture diversity, an indicator of social conformity, in terms of painted pottery, which was widespread across the Southwest during the periods we are considering. Previous studies (e.g., Plog 1980, Hegmon 1995, Kohler et al. 2004) have assessed diversity through detailed analyses of

Table 1. Population, ceramic, and settlement data for time-space units in the four regions of the US Southwest. Periods preceding major transformations are indicated.

Region	Subregion	Time (CE)	Population level†	Pop density Pop/km²	Dominant settlement form	Ware diversity
Hohokam	Middle Gila	950-1100	High	3.16	Lg villages, ballcourts	1.0
	Middle Gila	1100-1275	High	3.71	Lg villages, ballcourts, p.mds	1.0
	Middle Gila	1275-1300+	Highest	4.07	Lg villages, platform mounds	1.0
	Lower Salt	950-1100	High	3.73	Lg villages, ballcourts	1.0
	Lower Salt	1100-1275	High	5.23	Lg villages, ballcourts, p.mds	1.0
	Lower Salt	1275-1300+	Highest	6.08	Lg villages, platform mounds	1.6
	No. Periphery	950-1100	Highest	1.18	Lg villages, ballcourts	2.9
	No. Periphery	1100-1275	Moderate	0.50	House clusters	2.2
	No. Periphery	1275-1300+	Depop begins	0.41	House clusters	2.5
Mimbres	Upper Gila	1000-1130	Highest	0.61	Lg villages	1.1
	Upper Gila	1200-1300	Depop	0.03	Lg villages	3.0
	Upper Gila	1300-1450	Low	0.18	Lg villages	2.1
	Mimbres Valley	1000-1130	Highest	1.13	Lg villages	1.0
	Mimbres Valley	1130-1200‡	Depop		Few village rooms	
	Mimbres Valley	1200-1300	Low	0.22	Lg villages	4.0
	Mimbres Valley	1300-1450	Low	0.03	Lg villages	3.3
	Eastern	1000-1130	Highest	0.26	Lg villages	1.3
	Eastern	1130-1200	Low	0.16	Hamlets only	4.5
	Eastern	1200-1300	Highest	0.27	Lg villages	6.0
	Eastern	1300-1450	Low	0.02	Lg villages	4.3
Zuni	Central	900-1125	Moderate	0.61	Hamlets, Great houses	1.5
	Central	1125-1225	High	0.93	Hamlets	2.0
	Central	1225-1275	High	1.33	Lg villages, hamlets	2.3
	Central	1275-1325	Highest	1.61	Lg villages	3.0
	Central	1325-1400‡	High		Lg villages	
	Central	1400-1680	High	1.15	Largest villages	2.9
	Western	900-1125	Low	0.09	Hamlets, Great houses	1.9
	Western	1125-1225	Low	0.23	Hamlets	2.0

(con'd)

	Western	1225-1275	Moderate	0.54	Lg villages, hamlets	2.0
	Western	1275-1325	Low	0.28	Lg villages	3.0
	Western	1325-1400‡	Low		Lg villages	
	Western	1400-1680‡	Depop			
	Upper LC	1275-1325	Low	0.09	Lg villages, hamlets	4.0
	Upper LC	1325-1400‡	Low		Lg villages	
	Upper LC	1400-1680‡	Depop			
	El Morro	1225-1275	High	4.92	Lg villages, hamlets	2.2
	El Morro	1275-1325	Highest	5.31	Lg villages	3.0
	El Morro	1325-1400‡	Moderate		Lg villages	
	El Morro	1400-1680‡	Depop			
Salinas		1100-1300	High	1.08	Hamlets, few villages	2.0
		1300-1425	High	1.08	Lg villages	2.0
		1425-1600	Moderate	0.68	Largest villages	2.0
		1600-1700	Moderate	0.80	Largest villages	2.0

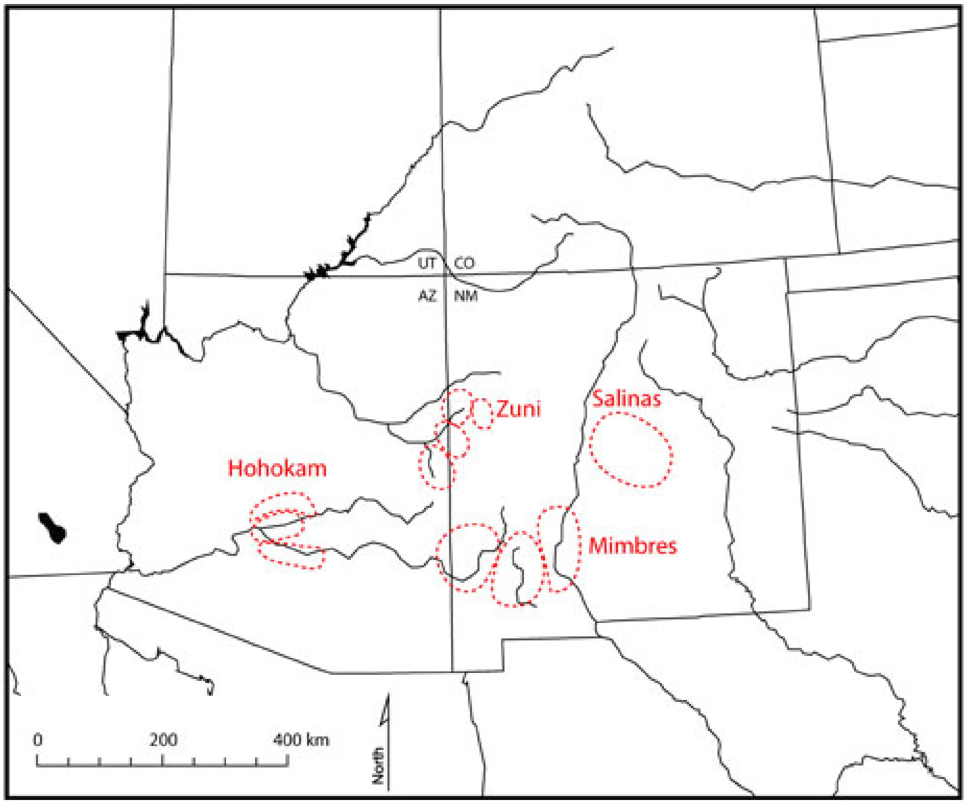
† Population levels relative to regional population only; not relative to entire Southwest.
‡ Not included in analysis for lack of either ceramic or population data.
Key: LC = Little Colorado, Lg = large, No. = Northern, p.mds = platform mounds, depop = depopulation of subregion.

variation in painted designs within a village or region. In contrast, here we focus on painted pottery wares allowing us to expand the analysis to a much broader spatial scale. “Ware” is a broad category that encompasses both technological and stylistic variables, such as the kinds of painted designs, the color of the clay paste and paint, and the kind of material used as temper; a given ware may include several more finely distinguished types, which are not considered here. Examples of several wares are described and illustrated below (Fig. 7).[1] The number of wares present in a given area at any one time is a result of both local production traditions and networks of exchange; thus our focus on wares provides insights into both the diversity of pottery made within an area and the diversity of interaction with other areas. Because our scope is broad, we use simple richness measures, i.e., number of wares present, as the basis for our analyses.

Analysis and results

To evaluate the relationship specified in our hypothesis at the broadest scale, we created maps of the distribution of painted pottery wares in the U. S. Southwest made during each of five centuries, beginning in 1000 CE. These were compiled using published sources that include maps or verbal descriptions of the range over which each ware is found. The wares included in these mappings are all those for which distributions are well documented in published literature (see endnote 1). Several of these wares are illustrated in Figures 3, 4, 5, and 7. Our analysis targets wares that were made in the areas that are the foci of our study and those commonly traded from other areas. However, the map does not include all painted pottery wares produced in the prehispanic Southwest. The illustrated ranges indicate areas where a given ware was found in appreciable quantities. Population centers are based on information from the

Fig. 6. Map of the U.S. Southwest showing four regions and all subregions used in this analysis.



Coalescent Communities database (Wilcox et al. 2003, Hill et al. 2004), which begins at approximately CE 1200.

Onto each distribution map we located the largest population concentrations during that century. Figure 8, illustrating pottery ware distributions and population centers for the 14th century, is one of the five maps. For every one of the five centuries, the greatest concentrations of population were in regions with the lowest number of different, co-occurring wares, consistent with our hypothesis: social conformity becomes increasingly important as population density increases, indicated by the association between low diversity and high density.

To evaluate this relationship with finer grained data, we used detailed population and ceramic data for the 35 time-space units (Table 1). To calculate population density for each unit, we first estimated the number of rooms in each settlement or acquired this information from published estimates. We then multiplied that figure by a constant number of people expected to occupy each dwelling. This constant differs from one region to the next and between some time periods because dwelling forms and sizes vary. Then the total population estimate of each subregion and time period was divided by the total occupied area of each subregion in square kilometers. This provides a density estimate in terms of people per square kilometer (Table 1). Population estimates for each case are based on large settlement databases compiled as part of the Long Term Vulnerability and Transformation NSF Biocomplexity project at Arizona State University. Though the methods differ slightly from case to case, the basic procedure was to place sites from each subregion and each time period into site size classes based on the best recorded examples of sites in each size class for a particular time period. Sites for which less information was available were placed in a rough site size category using the best information

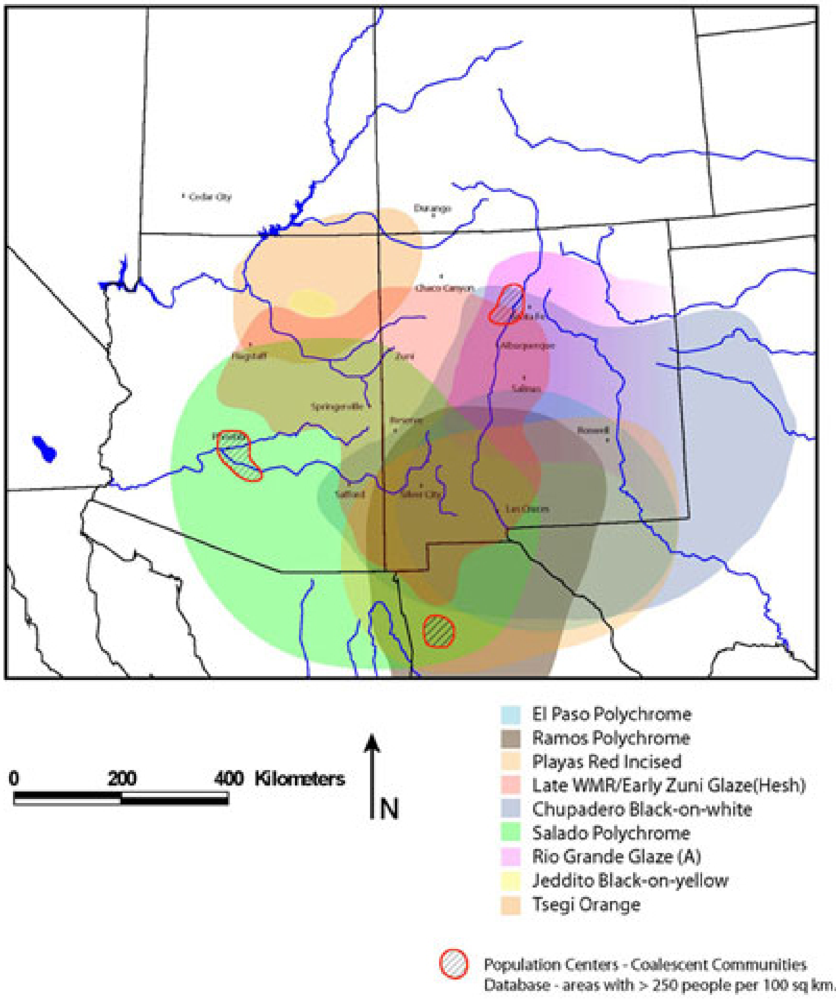
Fig. 7. Examples of several prehistoric Southwestern painted ceramic wares: a) White Mountain Redware, manufactured in the Zuni region; b) Salado Polychrome, manufactured mainly in central and eastern Arizona; c) Salinas Whiteware, manufactured in the Salinas region; d) Cibola Whiteware, manufactured in the Zuni region. Each ware exhibits differences in slip and paint colors, location of painted designs on vessel surfaces, and the arrangement of painted designs within the painted area.

available and were assigned the mean room count of sites in that size class. Room counts were then converted into population estimates and standardized for the length of the period using data from well studied sites in each subregion and time period.

We also extrapolated the number of small sites across unsurveyed areas using the information available in the most thoroughly surveyed portions of each subregion. We assume that a majority of large sites (> 30-40 rooms) in unsurveyed areas have already been located. Thus, we only extrapolated population based on the density of sites in the smallest size classes (< 30 rooms) from well surveyed areas. We have tested this procedure by comparing small site densities between surveyed areas and found that small site densities are relatively constant in well watered areas whether or not large villages are present. This suggests that the procedure likely provides a relatively good estimate of population in the unsurveyed areas.

The diversity of painted pottery wares associated with the population density was measured in two

Fig. 8. U.S. Southwest map showing the distribution of ceramic wares and of highest population concentrations, 1300 CE.



ways. First, we calculated a weighted average of the number of painted wares across all settlements within each time-space unit. Essentially, this is a measure of the material culture diversity experienced at the subregional level for our archaeological cases. The number of painted ceramics wares was determined on a site-by-site basis using painted sherd counts. A ceramic ware was included in the ware count for a site if it constituted one percent or more of the painted sherds in the ceramic assemblage. An average, weighted by the size of the sample of decorated sherds for each site, was calculated for each time-space unit. The weighted average mitigates the impact that small painted sherd samples have on site-level ware counts. Second, we calculated the range of diversity values within each subregion to determine the variation in diversity values among the villages within each subregion, which indicates whether people in different villages in the same subregion experienced the same amount of material culture diversity. Thus, the range provides a measure of homogeneity in regional interaction strategies. Both values are listed in Table 1.

The pattern is strong and consistent with our hypothesis. The greatest diversity of painted pottery wares occurs in the time-space units with the lowest population densities (Fig. 9). Although some time-space units with low population densities also have low diversities, none of those with high population densities have high diversities. Overall, material culture diversity is low in the contexts of the greatest concentration of people and the highest levels of diversity are always associated with extremely low population densities. Two time-space units in the Zuni region have somewhat more diversity than expected; we believe the population density for portions of this region has been overestimated because of frequent resettlement of villages at these times (Schachner 2007), but do not have adequate data to reassess the population values.

To examine the relationship between population density and painted pottery ware diversity in even more detail, we removed the seven time-space units with the highest densities of population, i.e., those with more than two people per square kilometer. Even with just the lower population densities included, the same relationship holds; there is a negative relationship between population density and ware diversity (Fig. 10). The Zuni cases skew the results somewhat, but do not deviate from the overall pattern.

It is possible that our results were determined by one or two large settlements within each subregion. To determine whether levels of diversity were representative of an entire subregion, we calculated the ranges of ware diversity. Twenty-seven of the 35 time-space units have range values of zero or one, indicating uniformity within subregions for the majority of cases. Three time-space units have range values of five: the eastern Mimbres area in 1300-1400 CE, and the Hohokam Northern Periphery area in 1100-1225, and in 1225-1300+ CE. Each of these time-space units postdates periods of major social transformation suggesting that people across these subregions may have been pursuing various kinds of strategies to cope with the aftermath of the transformations. We return to this issue in our discussion of transformations.

EXPLORING SOCIAL DIVERSITY AND SOCIAL TRANSFORMATION

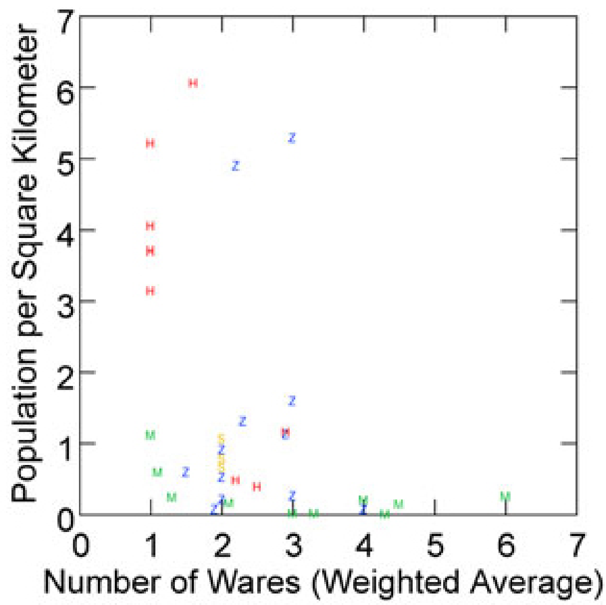
The association between our measures of conformity, i.e., low levels of material culture diversity, and high population density is quite striking, suggesting there might have been benefits to conformity in these situations. But what were the longer term consequences of this association? Did the loss of diversity contribute to a loss of resilience? We explore these questions as an initial step in contributing to discussions about potential effects of reduced social diversity. More specifically, we consider whether the low diversity contexts are associated with subsequent disruptive transformations. In pursuing this line of research, we do not suggest that reductions in diversity alone are a unilateral cause of the transformations. Rather, we examine the relationship as a first step toward understanding the role of diversity, in addition to a host of other factors including population density, in long-term processes in social-ecological systems.

Operationalizing concepts using archaeological data

We use some of the results of the fine-grained analysis of population density and ceramic diversity, limiting the data to those 13 time-space units that immediately preceded dramatic transformations and for which sufficient data on adjacent periods are available (Tables 1 and 2). For our purposes, a dramatic transformation is identified by changes in several domains of material culture (architectural and artifactual), settlement organization, and/or population that we judge represent the most significant changes in the lives of people living in these regions (for greater detail see Hegmon et al. 2008). “Dramatic” is a judgment call; every transition from one period to another (listed in Table 1) represents changes, but we focus on the most substantial changes. These include but are not limited to substantial declines in occupied dwelling area or number of settlements, changes in the forms of houses and community spaces, changes in the layout of settlements, and major changes in material culture in various domains, and changes in subregional or regional organization. Any one of the dramatic transformations includes only some of these changes. In Table 1 the periods immediately preceding dramatic transformations are indicated in red and blue, with red indicating a particularly severe transformation. The population density and ceramic diversity data for each period examined are listed in Table 2.

The transformations considered are of different sorts, but all involve population declines and/or

Fig. 9. Population density and ceramic ware diversity values for all time-space units, with region indicated by letter and color. H = Hohokam, M = Mimbres, S = Salinas, Z = Zuni.

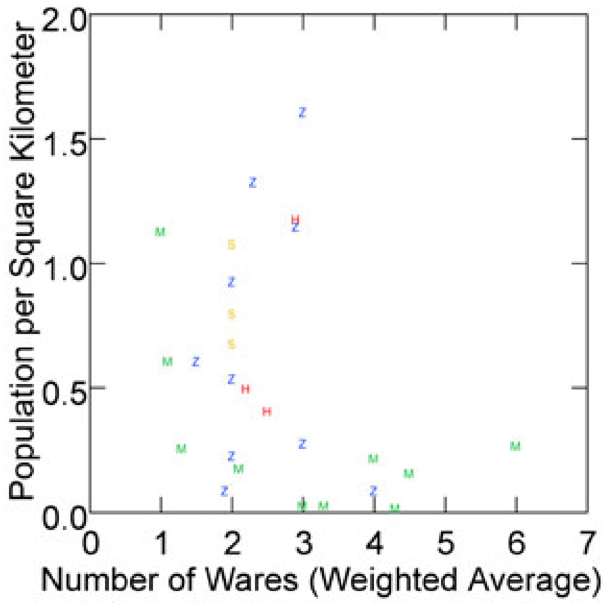


reorganizations, and many of the time-space units preceding major transformations were periods of relatively high population density. However, there is some variation among regions and subregions that affects our consideration of the relationships and bears discussion. No dramatic transformations were evident in the Salinas region during the period included in this study. Salinas has one of the most stable occupations in the entire U.S. Southwest (see Spielmann et al. 2011)

In the Mimbres case, all dramatic transformations are associated with considerable declines in population, although the first decline is from the largest populations known for the region to more modest levels, and the later decline is from much lower levels of population to essentially no resident population. In addition, the first dramatic transformation in the region, circa 1130 CE, involved substantial changes in material culture in many domains, i.e., houses, community spaces, tools, ceramic vessels, ornaments (see Hegmon et al. 1998, 2008, and Nelson 1999). During this transformation, villages in the three subregions were residentially abandoned and the region was partially depopulated, which included emigration by 80-95% of the population from the Mimbres Valley and Upper Gila subregions, respectively, but only a 40% reduction of the population in the Eastern Mimbres subregion. The remnant population reorganized, occupying small portions of residentially abandoned villages in the Mimbres Valley and small hamlets built from earlier field houses in the Eastern Mimbres subregion (Fig. 11). People constructed new kinds of houses and used new material styles alongside familiar, earlier styles. As noted in the analysis of ranges of diversity values within the Mimbres region, the villages of the early Postclassic had varied diversity values, indicating differences among villages. The second transformation (ca. 1450 CE) is less well studied and dated, but resulted in depopulation of the entire region by pueblo-dwelling people.

In the Hohokam region, the first dramatic transformation occurred in the 1100s CE, and involved a region-wide reorganization, characterized by a shift away from a long-established regional

Fig. 10. Population density and ceramic ware diversity values for all time-space units with densities below 3.0. Region indicated by letter and color. H = Hohokam, M = Mimbres, S = Salinas, Z = Zuni



network of ceremonial ball courts (Fig. 12) that had once served to convene large groups and as markets for exchange (Abbott et al. 2007). In the subsequent period, in some Hohokam subregions the ball courts were replaced by new forms of ritual and public architecture known as platform mounds. Social groups were balkanized around segments of the irrigation canal system and the platform mounds (Abbott et al. 2006). In the Lower Salt and Middle Gila subregions, population increased with this transformation, but in the Northern Periphery depopulation began, which continued through the next two centuries. The second dramatic transformation began in the 1300s CE and is marked by the near total depopulation of the Hohokam region, which was once occupied by as many as 40,000 people, and the abandonment of the most extensive prehistoric canal irrigation system in North America (Fig. 13). The remnant population was so ephemeral that villages are not archaeologically visible and population estimates cannot reasonably be made. This transformation began earlier in the Northern Periphery.

People in the Zuni region were involved in a dramatic transformation that took place in the late 1300s CE. The transformation is marked by a regional scale shift in population to the floodplains of the Zuni River in the Central Zuni subregion. By the late 1200s, most of the regional population was nucleated in large, compact pueblos and by the late 1300s all but the Central Zuni subregion was depopulated. The diverse methods of small-scale farming that characterized the pretransformation period shifted to a focus on irrigated farming on the floodplains in central Zuni. Thus, in the Zuni region as a whole, the regional scale reorganization that we characterize as a dramatic transformation was not associated with aggregate population decline, although subregions other than Central Zuni were depopulated.

Relationships of social diversity and population density with transformations

The 13 time-space units preceding dramatic transformations have a mix of diversity and density

Table 2. Characteristics of time-space units immediately preceding dramatic transformations.

Region	Subregion	Period	Population level[†]/ change following T	Ceramic diversity/ change following T
Hohokam	Middle Gila	950-1100	High, none	1.0, no change
	Middle Gila	1275-1300+	Highest, depop	1.0
	Lower Salt	950-1100	High, none	1.0, little change
	Lower Salt	1275-1300+	Highest, depop	1.6
	No. Periphery	950-1100	Highest, reduced	2.9, little change
Mimbres	Gila	1000-1130	Highest, depop	1.1, shifts to high
	Gila	1300-1450	Low, depop	2.1
	Mimbres Valley	1000-1130	Highest, depop	1.0, shifts to high
	Mimbres Valley	1300-1450	Low, depop	3.3
	Eastern	1000-1130	Highest, reduced	1.3, shifts to high
	Eastern	1300-1450	Low, depop	4.3
Zuni	Central	1275-1325	Highest, little change	3.0, no change
	Western	1275-1325	Low, low to depop	3.0

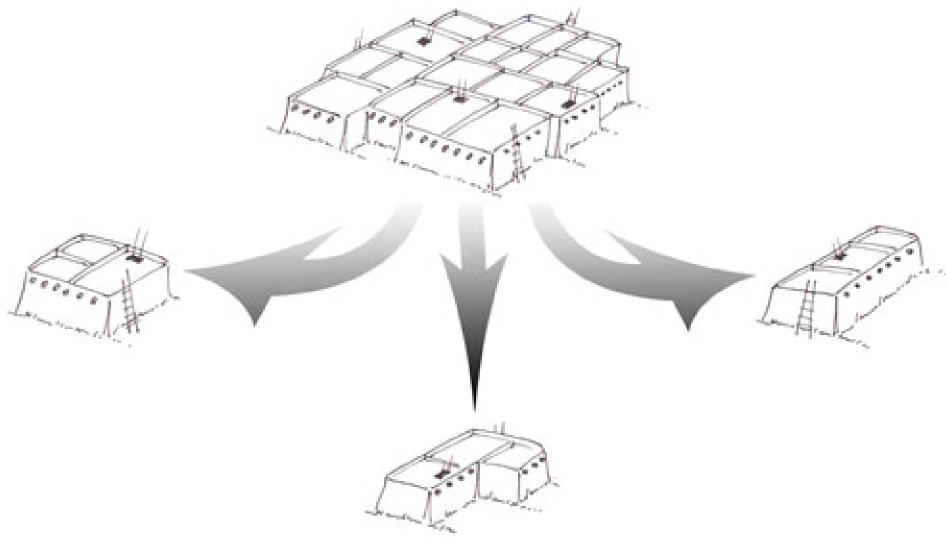
[†] characterized relative to levels within each region
Key: T = dramatic transformation, depop = depopulation of subregion

values (Table 2). Seven of the 13 time-space units preceding transformations, four in the Hohokam region and three in the Mimbres region, have extremely low ware diversities, less than 2.0, which is among the lowest of all 35 time-space units. All of these time-space units with low ware diversity values also are characterized by high population densities, in most cases the highest in the subregion history.

In the Mimbres region, the diversity values that precede the dramatic transformations are the lowest in the entire Mimbres sequence, and subsequent post-transformation values are considerably higher. Specifically, in the 1000-1130 CE period, the average ware diversity was 1.1, (with a range of 1.0-1.3), but in the subsequent periods of reorganization the diversity values increase considerably, with a range of 3.0-6.0. Population density follows the opposite pattern; it is highest before the transformation and lower after. Thus, the association of low ceramic diversity and high population density precedes transformations in the Mimbres region and is reversed following the transformation.

Most of the Hohokam cases also show low diversity and high population density preceding transformation. But close inspection of the Hohokam data reveals that the extremely low ware diversity in the Middle Gila and Lower Salt subregions was not unique to the periods preceding dramatic transformations. Extremely low ware diversity persisted throughout the sequence in those two subregions. The lack of change in diversity within the Middle Gila and Lower Salt subregions of Hohokam region differs from the pattern in the Mimbres region. Expanding our view of the Hohokam to the entire U.S.

Fig. 11. At the end of the Mimbres Classic Period (1130 CE) all villages in the Mimbres region were depopulated. In the eastern Mimbres subregion, people shifted to small hamlet settlements, remaining in the same areas.



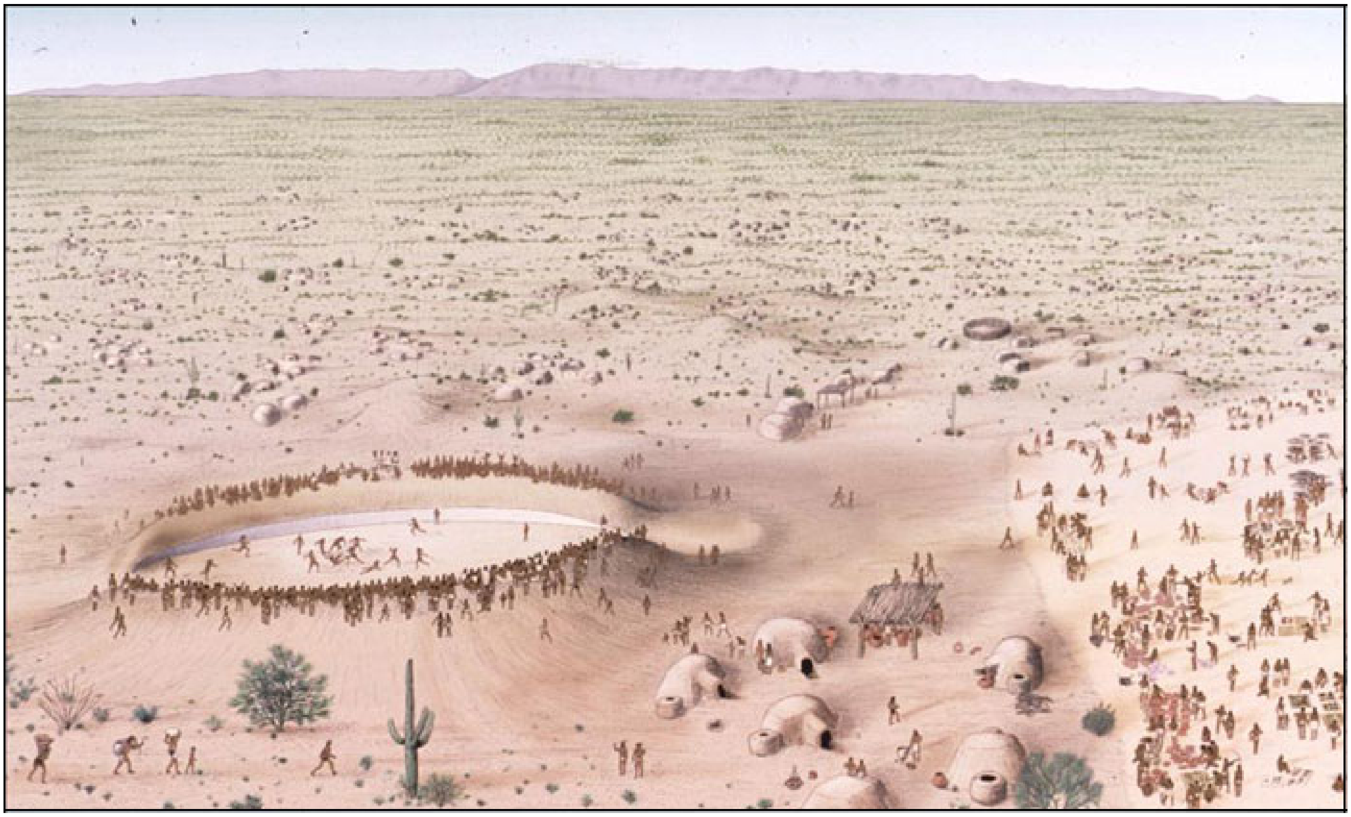
Southwest helps understand the consistently low diversity values. Hohokam population densities are far higher than those in other regions, which is generally true throughout the prehistory of the Southwest (Hill et al. 2004). Thus, the strong association between high population density and low material culture diversity persisted throughout the occupation of the Lower Salt and Middle Gila subregions of the Hohokam. The first dramatic transformation was not associated with a population decline in these two subregions, and ceramic ware diversities remained low, in accordance with our hypothesis. The second dramatic transformation was characterized by the largest decline of regional population in the prehistory of the U.S. Southwest and it is associated with a long history of extremely low ware diversity and extremely high population density.

Slightly over half of the periods preceding major transformations are characterized by low ceramic diversity and high population density. However, 6 of the 13 cases are not. All six are characterized by moderate to relatively high levels of ceramic diversity (2.1 - 4.3), two have relatively high population density, whereas four have relatively low population density. These include two Zuni time-space units, three of the Mimbres time-space units, and a time-space unit in the Northern Periphery of the Hohokam. Thus, there is not a strong pattern of association of either variable or of both variables with dramatic transformations, but low ceramic diversity and high population density are slightly more often associated with major transformations than not. We have not established that either high population density or reduced social diversity are causes of major transformation but that they should be considered when thinking about factors that may influence the resilience of social systems. It is possible that high population density alone is a major contributing factor, although among our cases, 4 of the 13 periods that immediately preceded dramatic transformations had relatively low population density.

DISCUSSION

In this study of relationships among population density, social diversity, and transformation, we found that for the middle range societies of the prehistoric and early historic U.S. Southwest, diversity, assessed in terms of material culture, is strongly, inversely related to population density and

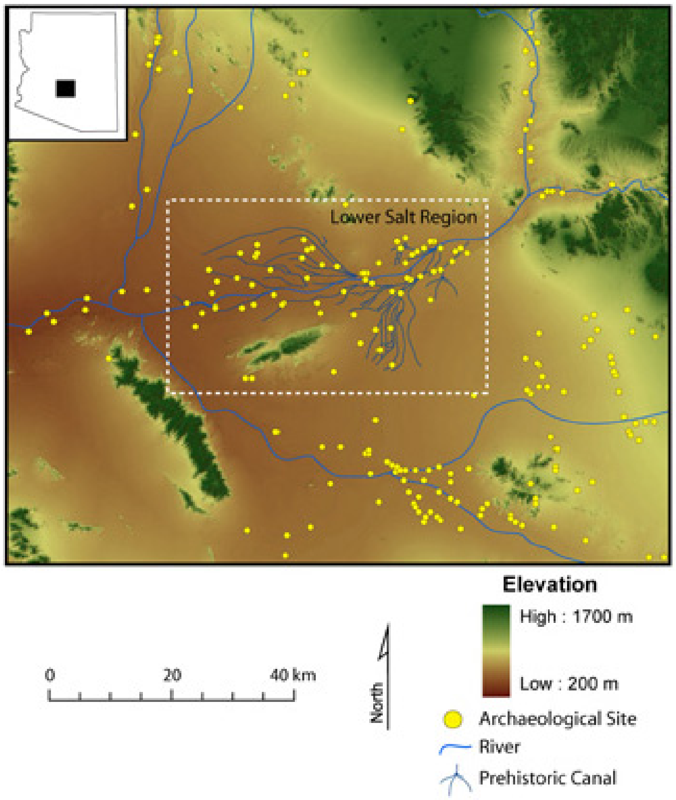
Fig. 12. Hohokam ball courts were ceremonial, social, and market centers for a vast regional population. Copyright by Western National Parks Association. Used by permission.



that in some contexts, low levels of diversity and high population density preceded dramatic social, economic, political, and demographic transformations. These results suggest a trade-off between the costs and benefits of this kind of diversity in the context of population density, which may be intentional or an emergent circumstance. As we noted at the start of this paper, Folke (2006) points out that diversity is essential for absorbing disturbance and helping with regeneration and reorganization following disturbance, a concept he has applied to biological and social realms (Folke et al. 2002). Other ecologists and social scientists interested in resilience and diversity concur that diversity can enhance resilience, although the relationships are complex (Chapin et al 1997, Walker et al. 1999, 2006, Elmqvist et al. 2003, Low et al. 2003, Ostrom 2005, Ives and Carpenter 2007).

To explore possible applications of these ideas to the social realm, we examined whether low levels of diversity in material culture, indicative behavioral conformity and observed in contexts of relatively high population density, might also be associated with reductions in resilience, evident as major social transformations. We noted that low diversity and conformity might contribute to decision making and the capacity for collective action, and thus might contribute to robustness in the short term. However, by limiting the range of options, these same processes could erode resilience and thus increase vulnerability in the long term. This trade-off was apparent in some but not all cases, with periods of high density and conformity followed by dramatic transformations involving depopulation and/or reorganization. However, there were nearly as many cases in which major transformations were not preceded by either high population density or low levels of ceramic diversity, so their relationships to reduced resilience are unclear and require further research.

Fig. 13. The Hohokam canal system in central Arizona was the largest prehistoric water control system in North America.



Our hypothesis that social conformity in middle range societies is influenced by population density, such that low levels of material culture diversity are associated with high degrees of population density, was supported by a strong inverse relationship between the diversity of painted pottery wares and population density. Across 35 time-space units from four regions in the U.S. Southwest, high levels of population density are associated with low ware diversities and the highest ware diversities occur only in the units with extremely low population densities. This result helps us understand why reduction in some kinds of diversity in the social realm may occur, persist, and perhaps be difficult to counteract in middle range or tribal societies. Intentionally or not, these circumstances result in a process we label "resisting diversity." We have attributed this outcome to the need for cooperation in situations of high population density, part of the process of the evolution of tribal social networks described by Braun and Plog (1982). Social practices contributing to that cooperation would include some degree of ideational and behavioral conformity, which would be manifest in material homogeneity. The patterns we identified could also be influenced by aggregation and its effects on conformist transmission. Specifically, biased conformist transmission is said to result in reductions in diversity over what might be expected at higher population density levels, and living in aggregates favors conformity because individuals will select the most frequent trait or behavior to imitate (see Boyd and Richerson 1985, Henrich 2001, Kohler et al. 2004). These explanations are not contradictory and may, in fact, work in tandem; further investigation relating the two perspectives is warranted.

We also examined ceramic diversity and population density values across periods of dramatic transformation in our four archaeological sequences. Reductions in material culture diversity associated with increases in population density occurred in periods preceding approximately half of the dramatic transformations. In these cases, conformity in the context of population diversity may have solved the most pressing, immediate disturbances, but increased vulnerability to other, large infrequent disturbances. Or population density may have created conditions that reduced resilience, such as food stress, environmental degradation, and social conflict in which low levels of social diversity contributed to difficulty in changing to address those conditions. These ideas are suggestions that require further examination, but they illustrate that over long time spans we can see consistency in the conditions that may depress social diversity and that may also contribute to reductions in resilience.

We found that dramatic transformations in all three subregions of the Mimbres and two subregions of the Hohokam immediately followed periods in which diversity, assessed in terms of painted pottery wares, was relatively low and population density was relatively high. In the Mimbres region, increases in diversity immediately followed as part of the transformation, as Folke's (2006) perspective on the value of diversity for reorganization might suggest. But in the Hohokam region, ceramic ware diversity did not increase substantially following these transformations nor did population decline. The transformations of the 1100s in the Hohokam Lower Salt and Middle Gila subregions were social, economic, and religious reorganizations in the context of a stable or growing population that became more regionally concentrated. The high levels of population, among the highest in the prehistory of the U.S. Southwest, may have demanded a level of social conformity or created the demographic context for strong biased conformist transmission, evident in low ceramic ware diversities, that was compelling enough to social action that people continued to conform. Alternatively, people may have fallen into a rigidity trap (Hegmon et al. 2008) in which their behavior, while potentially harmful, was continued. We have many examples of the persistence of harmful practices in our contemporary world. This kind of path dependence is discussed for the prehistoric U. S. Southwest by Hegmon and others (Hegmon et al. 2008). We can only wonder whether, in the Hohokam region, the massive canal systems, high population levels, and economic, political, and social systems that supported them might have persisted had people embraced greater diversity and not adopted a balkanized stance relative to one another.

FUTURE RESEARCH DIRECTIONS

This exploration of ceramic diversity and population density, and the mapping of those results to major transformations suggest that population conditions may influence social diversity, at least in middle range societies, and that these may play a role in reduced social resilience. Although our results of tracking transformations with respect to these variables was mixed, there are enough cases where low social diversity and relatively high population density immediately preceded transformations that we should be concerned about conditions that influence social diversity.

In our research we do not attribute causal status to any variables, but future research could entail examining potential causal relationships between population density and social diversity and their role in precipitating social transformations. There are many ways to examine potential causes, but we suggest two. First, in a previous study of one area on the Pajarito Plateau in northern New Mexico, Kohler et al concluded: "We take conformity in ceramic design to be one symptom in a developing social system that places great value on within-group cooperation, helping alleviate cooperative dilemmas" (Kohler et al. 2004:100). They associate these dilemmas for their case with increases in population aggregation or density. It may be the "cooperative dilemmas" that are at the heart of the issues contributing to transformations and that the ceramic homogeneity we and they saw would be expressed only with certain kinds of social challenges. As we have noted, the societies in the prehistoric U.S. Southwest had poorly developed decision making hierarchies in most cases, favoring cooperative decision making.

Second, increases in population density are associated with increases in resource exploitation and potentially an increased impact on resource productivity and other aspects of ecosystems. Thus, as we have discussed above, it is possible that transformations were caused primarily by the consequences of increased population on resource provisioning and ecosystem conditions, and that the decreases in material diversity that we observe are simply epiphenomena. However, the decreased diversity of ideas and behaviors implied by decreased material diversity might exacerbate this condition, as well as the condition of connectivity described above. A more detailed analysis of these relationships is needed.

In the contemporary world, many people live in tribal societies in which conformity supports group action and decision making. Although the call for social diversity has clear advantages and can be supported in complex states and nations, it also may have disadvantages in tribal societies at certain levels of population density. The trade-offs and causal relationships deserve careful attention.

[1] The following wares are included in samples from one or more time-space unit for the fine-grained analysis for Hypothesis 1: Hohokam Red-on-buff*, Mogollon Brownware (Mimbres Black-on-white*), Cibola White Ware*, White Mountain Red Ware Series*, Mesa Verde Black-on-white* (Magdalena), Salado Polychrome*, Tusayan White Ware (Series)*, Chihuahuan Ware*, Jornada Ware*, Rio Grande White Ware*, Rio Grande Glazeware*, Zuni/Acoma Glazeware*, Hopi Yellow Ware*, Tsegi Orange Ware*, San Juan Red Ware, Little Colorado White Ware, Puerco Valley Red Ware, Tuzigoot White-on-red (Salt W/r), Zuni Buff Ware, Zuni Polychrome. Those indicated with an asterisk were also included in the pan-regional maps because their distributions are well documented in published sources.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol16/iss1/art25/responses/

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